AMENDMENTS TO THE DRAWINGS

The attached sheets of drawings include changes to Figs (14-15). The sheet, which includes Figs. (14-15), replace the original sheets including Figs (14-15).

Enclosure(s):   Replacement Sheets: 2 (two)

REMARKS

Claims 1-16 are pending in the application.

Claims 1-16 are allowed.

The Specification is objected to by the Examiner.

The Drawings have been objected to by the Examiner.

The Abstract is objected to by the Examiner.

Detailed Comments

Specification

The Applicants respectfully submits a revised Specification to overcome the noted objections. A redlined version of the Specification is also attached. The Applicants also submits a revised Abstract to overcome the objections noted thereto.

Drawings

The Applicants respectfully submits a revised version of Figs. 14-15 duly marked "Prior Art" to overcome the objections noted. Thus, Applicants respectfully request acknowledgement that these Corrected Drawings are acceptable.

In view of the above, reconsideration and allowance of this application are now believed to be in order, and such actions are hereby solicited. If any points remain in issue which the Examiner feels may be best resolved through a personal or telephone interview, the Examiner is kindly requested to contact the undersigned at the telephone number listed below.

The USPTO is directed and authorized to charge all required fees, except for the Issue

Fee and the Publication Fee, to Deposit Account No. 19-4880. Please also credit any

overpayments to said Deposit Account.

Respectfully submitted,

/Chidambaram.S.Iyer/

SUGHRUE MION, PLLC   Chid S. Iyer
Telephone: (202) 293-7060   Registration No. 43,355
Facsimile: (202) 293-7860
WASHINGTON DC SUGHRUE/265550
   65565
   CUSTOMER NUMBER
Date: December 2, 2008

DESCRIPTION

METHOD OF BRAKING INDUCTION MOTOR AND

CONTROL APPARATUS

Technical Field

[0001]

The present invention relates to an induction motor control device for stopping an induction motor, and more particularly, to a braking method and apparatus for controlling torque shock, caused by an abrupt change of an output current phase when a switch-over from a normal driving state to a direct current (DC) braking state is performed, to be reduced to a predetermined value or less by predictably operating an output voltage phase for flowing out a direction current.

Related Art

[0002]

On a conventional direct current (DC) braking function of an induction motor, a DC braking technique that is embedded in a high performance vector control device and not tripped (an abnormal stop of a control device) and a DC braking technique

having a small vibration during the induction motor is stopped are disclosed (for example, refer to a patent document 1). When the control device is tripped, the control device is abnormally stopped, and simultaneously, an alarm is displayed on a display part.

Fig. 14 is a block diagram illustrating a detailed example of a vector control device having a velocity sensor. The reference numeral 101 denotes a DC braking control arithmetic unit, which operates as shown in the flow chart of Fig. 15. The reference numeral 102 denotes a velocity control arithmetic unit, in which a torque current (corresponding to a torque) instruction iq* is operated on the basis on a velocity instruction ω input from external systems of the vector control device and a velocity detection value ωr (hereinafter, the reference symbol * denotes an instruction value). The reference numeral 103 denotes a magnetic flux arithmetic unit, where iq* is input, a magnetic flux dividing current instruction id* and a sliding frequency ωs that satisfy a vector control condition are operated to output id*, iq*, and ws. The reference numeral 104 denotes a d-p axis ACR which operates voltage instructions vq* and vd* for

allowing current detection values iq and id to follow iq* and id*. The reference numeral 105 denotes an inverse d-q converter, which converts vq* and vd* from a rotation coordinate d-q axis into a three phase voltage instruction. The reference numeral 106 denotes a PWM arithmetic unit, which operates a firing pattern for turning on/off a switching element on the basis of a three phase voltage instruction. The reference numeral 107 denotes a power conversion circuit. The reference numeral 108 denotes a slip compensation arithmetic unit, which receives the output from the magnetic flux arithmetic unit 103 to operate a primary frequency ω1 of the induction motor. The reference numeral 109 denotes an integrator, which integrates the primary frequency ω1 and computes a phase θ1 on a d-axis to output them to the d-q converter 111 or the inverse d-q converter 105. The reference numeral 110 denotes a velocity detection arithmetic unit, which operates the velocity based on the signal from the position detector such as an encoder or performs a velocity estimation based on a current or the like if the position detection does not exist. The reference numeral 111 denotes a d-q converter, which operates current detection values id and iq

converted into rotation coordinates with respect to a phase θ1 of a d-axis. The reference numeral 112 denotes a position detector such as an encoder, and the reference numeral 113 denotes an induction motor, which includes switches S101, S103, and S104 controlled by the DC braking control arithmetic unit 101. The DC braking control arithmetic unit 101 receives a braking force target value of the DC braking and a DC braking instruction (not shown in the drawing) used to switch over to the DC braking drive. When the vector control is performed, the switches S101, S103, and S104 are switched over to the side of "a" by the DC braking control arithmetic unit 1, and the vector control is performed as described above.

Referring to Fig. 15, in a step 201, the phase of a voltage vector θv is calculated only at an instant that a switch-over from the vector control to the DC braking is performed. In the step 202, the switch S101 is switched over to the side of "b" to input θv into θdq. In the step 203, the switch S103 is switched over to the side of "b" to input the instruction id* of the ACR of the d-axis and the value corresponding to the braking force input to the DC braking control arithmetic unit 101 to the

ACR 104 of the d-q axis, so that the instruction iq*
of the ACR of the q-axis is set to 0. In a step 204,
an absolute value of "iq" and a predetermined
reference value "α" are compared. In the step 205a,
if the absolute value "iq" is larger than the
reference value "α", the switch S104 is switched
over to the side of "a", so that the output of the
ACR 104 of the d-q axis is delivered to the PWM
arithmetic unit 106. In a step 205b, if the absolute
value of "iq" is smaller than the reference value
"α", the switch S104 is switched over to the side of
"b", the output of the ACR of the d-axis is
validated, the q-axis voltage instruction Vq* is set
to zero (Vq*=0, i.e., the ACR of the q-axis is
invalidated), and the voltage instruction is output
to the PWM arithmetic unit 106. Through the steps
204 and 205, it is possible to prevent vibration
generated when a rotor position determination of an
alternating current (AC) motor is stopped.

As described above, in a conventional induction
motor control apparatus and its control method, the
phase of the vector θv is calculated only at an
instant that a switch-over from the vector control
to the DC braking is performed, "θv" is input to
"θdq", the instruction iq* of the ACR of the q-axis

is set to 0, and a control is performed by the ACR
104 of the d-q axis. Then, if the absolute value iq
is smaller than the predetermined reference value α,
the ACR of the q-axis is invalidated.

Patent Document 1: WO 98/11663, Figs. 1 and 2

Problems to be solved by the Invention

[0003]

The conventional induction motor control device
and its control method discloses a DC braking method
in the control device of the induction motor, in
which the current supplied from the power conversing
device is divided by vector components to perform a
control. In addition, as described in the patent
document 1 that torque is not generated in a low
velocity range in the case of a V/f control, the DC
braking is initiated when the frequency is equal to
or lower than the setup DC braking initiation
frequency in the V/f control. However, when the
method disclosed in the patent document 1 is
executed, it is impossible to set a variation of the
current phase to be equal to or lower than a
predetermined value because the setup DC braking
initiation frequency is different from the rotation
information of the induction motor. In addition, in

both of the vector controls that a velocity sensor is installed and the velocity sensor is not installed, if the rotation number is equal to or lower than a predetermined value at the state that the phase of the current instruction is fixed, it is necessary to fix the voltage phase, and other complicated processes are also generated. Furthermore, when the ACR 104 of the d-q axis is used to perform the control during the DC braking, the voltage phase is changed because the voltage instruction Vd* of the d-axis and the voltage instruction Vq* of the q-axis vary, so that a DC voltage and a DC current cannot be output.

The present invention is contrived solve the aforementioned problems, and is to provide a control apparatus and a braking method, by which an abrupt change of the current phase is inhibited and the torque shock can be reduced to a predetermined value or less when a switch-over from the normal control state to a DC braking state is performed by predictably operating the output voltage phase during the DC braking on the basis of the output voltage phase in a normal control state.

Means for Solving the Problems

[0004]

In order to solve the aforementioned problems, the present invention provides the following methods and apparatuses.

[0005]

An aspect of the ~~The~~ present invention ~~disclosed in claim 1~~ is a direct current (DC) braking method for stopping an induction motor using a control device including: a power converter for driving the induction motor, a PWM arithmetic unit for determining a switching pattern of the power converter on the basis of a primary voltage instruction and an output phase obtained by adding a voltage phase and a magnetic flux phase, a voltage arithmetic unit, a torque current controller and an excitation current controller, wherein torque shock generated by an abrupt change of an output current phase is reduced to a predetermined value or less by predictably operating an output voltage phase during the DC braking on the basis of an output voltage phase of a normal control state, when a switch-over from the normal control state to a DC braking state is performed.

[0006]

~~In the invention disclosed in claim 2~~ More

specifically, the output voltage phase during the DC braking is predictably operated on the basis of an output voltage phase of the normal control state and a phase advanced until the DC braking is initiated.

[0007]

~~In the invention disclosed in claim 3~~In another specific enhancement, the phase advanced until the DC braking is initiated is operated on the basis of a setup DC braking initiation frequency.

[0008]

In ~~the invention disclosed in claim 4~~another specific enhancement, the phase advanced until the DC braking is initiated is operated on the basis of a deceleration rate and a setup DC braking initiation frequency.

[0009]

In ~~the invention disclosed in claim 5~~another specific enhancement, the torque shock during a restart is reduced to a predetermined value or less by controlling the output voltage phase during the DC braking with respect to a coordinate axis for a normal control.

[0010]

~~The invention disclosed in claim 6~~Another aspect of the present invention is a control device

capable of a DC braking for stopping an induction motor, the control device including: a power converter for driving the induction motor; a PWM arithmetic unit for determining a switching pattern of the power converter on the basis of a primary voltage instruction and an output phase obtained by adding a voltage phase and a magnetic flux phase; a voltage arithmetic unit; a torque current controller; and an excitation voltage controller, wherein torque shock generated by an abrupt change of an output current phase is reduced to a predetermined value or less by predictably operating an output voltage phase during the DC braking on the basis of an output voltage phase of a normal control state, when a switch-over from the normal control state to a DC braking state is performed.

[0011]

~~In the invention disclosed in claim 7~~More specifically, the output voltage phase during the DC braking is predictably operated on the basis of an output voltage phase of the normal control state and a phase advanced until the DC braking is initiated.

[0012]

In ~~the invention disclosed in claim 8~~another specific enhancement, the phase advanced until the

DC braking is initiated is operated on the basis of a setup DC braking initiation frequency.

[0013]

In another specific enhancement~~the invention disclosed in claim 9~~, the phase advanced until the DC braking is initiated is operated on the basis of a deceleration rate and a setup DC braking initiation frequency.

[0014]

In another specific enhancement~~the invention disclosed in claim 10~~, the torque shock during a restart is reduced to a predetermined value or less by controlling the output voltage phase during the DC braking with respect to a coordinate axis for a normal control.

Advantage of the Invention

[0015]

According to an aspect of the present ~~the~~ invention ~~disclosed in claim 1~~, in a DC braking method for stopping the induction motor, torque shock generated by an abrupt change of an output current phase can be reduced to a predetermined value or less by predictably operating an output voltage phase during a DC braking on the basis of an

output voltage phase of a normal control state when a switch-over from the normal control state to a DC braking state is performed.

~~According to the invention disclosed in claim 2~~More specifically, since the output voltage phase during the DC braking can be operated on the basis of the output voltage phase of the normal control state the phase advanced until the DC braking is initiated, it is possible to reduce the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

~~According to the invention disclosed in claim 3~~More specifically, since the phase advanced until the DC braking is initiated can be calculated on the basis of a setup DC braking initiation frequency, it is possible to reduce the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

~~According to the invention disclosed in claim 4~~More specifically, since the phase advanced until the DC braking is initiated can be operated on the basis of the deceleration rate and the setup DC braking initiation frequency, it is possible to reduce the torque shock generated by an abrupt change of the output current phase to a

predetermined value or less.

~~According to the invention disclosed in claim 5~~More specifically, it is possible to reduce a torque shock generated during a restart to a predetermined value or less by controlling the output voltage phase during the DC braking, predicted by the method of predictably operating the output voltage phase during the DC braking, with respect to the coordinate axis of the normal control.

According to another aspect of the invention ~~disclosed in claim 6~~, in an apparatus for controlling the induction motor, the torque shock generated by an abrupt change of the output current phase can be reduced to a predetermined value or less by predictably operating the output voltage phase during a DC braking on the basis of the output voltage phase of the normal control state when a switch-over from the normal control state to a DC braking state is performed.

~~According to the invention disclosed in claim 7~~More specifically, since the output voltage phase during the DC braking can be operated on the basis of the output voltage phase of the normal control state the phase advanced until the DC braking is initiated, it is possible to provide a control

device capable of reducing the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

~~According to the invention disclosed in claim 8~~More specifically, since the phase advanced until the DC braking is initiated can be calculated on the basis of a setup DC braking initiation frequency, it is possible to provide a control device capable of reducing the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

~~According to the invention disclosed in claim 9~~More specifically, since the phase advanced until the DC braking is initiated can be operated on the basis of the deceleration rate and the setup DC braking initiation frequency, it is possible to provide a control device capable of reducing the torque shock generated by an abrupt change of the output current phase to a predetermined value or less.

~~According to the invention disclosed in claim 10~~More specifically, it is possible to provide a control device capable of reducing the torque shock generated during a restart to a predetermined value or less by controlling the output voltage phase

during the DC braking, predicted by the method of predictably operating the output voltage phase during the DC braking, with respect to the coordinate axis of the normal control.

Brief Description of the Drawings

[0016]

[Fig. 1]

Fig. 1 is a flowchart illustrating a method of applying a control device of an induction motor according to the first embodiment of the present invention.

[Fig. 2]

Fig. 2 is a flowchart illustrating a processing sequence of a method according to the present invention.

[Fig. 3]

Fig. 3 is a flowchart illustrating a method of applying a control device of an induction motor according to the second embodiment of the present invention.

[Fig. 4]

Fig. 4 is a block diagram illustrating a control device of an induction motor for applying a method according to the third embodiment of the

present invention.

[Fig. 5]

Fig. 5 is a block diagram illustrating a control device of an induction motor for applying a method according to the fourth embodiment of the present invention.

[Fig. 6]

Fig. 6 is a block diagram illustrating a control device of an induction motor for applying a method according to the fifth embodiment of the present invention.

[Fig. 7]

Fig. 7 is a block diagram illustrating a control device of an induction motor for applying a method according to the sixth embodiment of the present invention.

[Fig. 8]

Fig. 8 is a block diagram illustrating a control device of an induction motor for applying a method according to the seventh embodiment of the present invention.

[Fig. 9]

Fig. 9 is a block diagram illustrating a control device of an induction motor for applying a method according to the eighth embodiment of the

present invention.

[Fig. 10]

Fig. 10 is a block diagram illustrating a control device of an induction motor for applying a method according to the ninth embodiment of the present invention.

[Fig. 11]

Fig. 11 is a block diagram illustrating a control device of an induction motor for applying a method according to the tenth embodiment of the present invention.

[Fig. 12]

Fig. 12 is a block diagram illustrating a control device of an induction motor for applying a method according to the eleventh embodiment of the present invention.

[Fig. 13]

Fig. 13 is a block diagram illustrating a control device of an induction motor for applying a method according to the twelfth embodiment of the present invention.

[Fig. 14]

Fig. 14 is a block diagram illustrating a construction of an induction motor control device for applying a conventional method.

[Fig. 15]

Fig. 15 is a flowchart illustrating a processing sequence of a conventional method.

Description of Reference Numerals and Signs

[0017]

1: POWER CONVERTER

2: AC MOTOR

3: CURRENT DETECTOR

4: d-q CONVERTER

5: TORQUE CURRENT CONTROLLER

6: EXCITATION CURRENT CONTROLLER

7: PHASE CONVERTER

8: INTEGRATOR

9: VOLTAGE ARITHMETIC UNIT

10: PWM ARITHMETIC UNIT

11: VOLTAGE PHASE PREDICTION ARITHMETIC UNIT

12: PHASE PREDICTOR

13: PRIMARY CURRENT CONTROLLER

101: DC BRAKING CONTROL ARITHMETIC UNIT

102: VELOCITY CONTROL ARITHMETIC UNIT

103: MAGNETIC FLUX ARITHMETIC UNIT

104: d and q AXES ACR

105: INVERSE d-q CONVERTER

106: PWM ARITHMETIC UNIT

107: POWER CONVERSION CIRCUIT

108: SLIDING COMPENSATION ARITHMETIC UNIT

109: INTEGRATOR

110: VELOCITY DETECTION ARITHMETIC UNIT

111: d-q CONVERSION UNIT

112: POSITION DETECTOR

113: INDUCTION MOTOR

114: BRAKING FORCE TARGET VALUE OF DC BRAKING

S1, S2, S3, S4, S101, S103 and S104: SWITCHES

Best Mode for Carrying Out the Invention

[0018]

Hereinafter, the embodiments of the present invention will be described in detail with reference to the accompanying drawings.

Embodiment 1

[0019]

Fig. 1 is a flowchart illustrating a control device of an induction motor for applying a method according the first embodiment of the invention, and Fig. 2 is a flowchart illustrating a processing sequence of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q

converter 4, a torque current controller 5, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S1, S2, and S3. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value iq and an excitation current detection value id. The torque current controller 5 operates the q-axis voltage correction value Vqc such that the received torque current instruction value iq* corresponds with the torque current detection value iq. The excitation current controller 6 operates the d-axis voltage correction value Vdc so that the received excitation current instruction value id* corresponds with the excitation current detection value id. The phase converter 7 converts the received frequency f1* into a phase amount Δθdq between the samplings. The

integrator 8 integrates the value Δθdq output from the phase converter 7 to operate a magnetic flux phase θdq. The voltage arithmetic unit 9 operates a primary voltage instruction V1* and a voltage phase θ using the following equation, on the basis of a d-axis voltage instruction Vd*' obtained by adding the received d-axis voltage instruction Vd* and the d-axis voltage correction value Vdc by setting a q-axis voltage instruction Vq*' to zero or a value obtained by adding the q-axis voltage correction value Vqc and the q-axis voltage instruction Vq* given by the switch S1.

[0020]

[Equation 1]

$$V1* = \sqrt{Vd*^2 + Vq*^2} \qquad (1)$$

$$\theta = \tan^{-1}\frac{Vq*}{Vd*} \qquad (2)$$

[0021]

The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase prediction arithmetic unit 11 predictably operates

the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value Δθdq output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount Δθdq between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f1* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S3 are operated in the side of "a" as

the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction Vq*' obtained by adding the received q-axis voltage instruction Vq* and the q-axis voltage correction value Vqc, and the d-axis voltage instruction Vd*' obtained by adding the received d-axis voltage instruction Vd* and the d-axis voltage correction value Vdc are input to the voltage arithmetic unit 9. The phase amount ΔΘdq between the samplings is operated by the phase converter 7 on the basis of the received frequency f1*, and the magnetic flux phase Θdq is operated by the integrator 8. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1 and S2 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq*' is set to zero (Vq*'=0), and the phase amount ΔΘdq between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process

advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, so that a value obtained by adding a voltage phase of the normal control state and the phase amount $\Delta\theta dq$ obtained in the step 2a is substituted for the magnetic flux phase θdq to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θdq.

In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so

that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 2

[0022]

Fig. 3 is a block diagram illustrating a control device of an induction motor for applying a method according to the second embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2,

a current detector 3, a d-q converter 4, a torque current controller 5, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value iq and an excitation current detection value id. The torque current controller 5 operates the q-axis voltage correction value Vqc such that the received torque current instruction value iq* corresponds with the torque current detection value iq. The excitation current controller 6 operates the d-axis voltage correction value Vdc such that the received excitation current instruction value id* corresponds with the excitation current detection value id. The phase converter 7 converts the received frequency f1* into a phase amount Δθdq between the samplings.

The integrator 8 integrates the value Δθdq output from the phase converter 7 to operate the magnetic flux phase θdq. The voltage arithmetic unit 9 operates a primary voltage instruction V1* and a voltage phase θ, on the basis of a q-axis voltage instruction Vq*' obtained by adding the q-axis voltage correction value Vqc and the received q-axis voltage instruction Vq* by setting the d-axis voltage instruction Vd*' to zero or a value obtained by adding the d-axis voltage correction value Vdc and the d-axis voltage instruction Vd* given by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state is performed and the value Δθdq output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship

between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount Δθdq between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f1* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S2 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction Vq*' obtained by adding the received q-axis voltage instruction Vq* and the q-axis voltage correction value Vqc, and the d-axis voltage instruction Vd*' obtained by adding the received d-axis voltage

instruction Vd* and the d-axis voltage correction value Vdc are input to the voltage arithmetic unit 9. The phase amount Δθdq between the samplings is operated by the phase converter 7 on the basis of the received frequency f1*, and the magnetic flux phase θdq is operated by the integrator 8. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S2 and S4 re switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq*' is set to zero (Vq*'=0), and the phase amount Δθdq between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the voltage phase θv of the normal control state

is rotate by 90°. However, its rotation direction is determined by the sign of the received frequency f1*. A valued obtained by adding this phase angle and the phase amount Δθdq obtained in the step 2a is substituted for the magnetic flux phase θdq to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θdq.

In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the

induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 3

[0023]

Fig. 4 is a block diagram illustrating a control device of an induction motor for applying a method according to the third embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a torque current controller 5, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13,

and switches S1, S2, S3, and S4. The power converter
1 converts a three phase AC current into a DC
voltage having a predetermined frequency and voltage
using a power element through a PWM control method
and supplies it to the induction motor 2. The
current detector 3 detects the current supplied to
the induction motor 2. The d-q converter 4 separates
the current detected by the current detector 3 into
a torque current detection value iq and an
excitation current detection value id. In addition,
the primary current detection value i1 is output.
The torque current controller 5 operates the q-axis
voltage correction value Vqc so that a received
torque current instruction value iq* corresponds
with the torque current detection value iq. The
excitation current controller 6 operates the d-axis
voltage correction value Vdc so that the received
excitation current instruction value id* corresponds
with the excitation current detection value id. The
phase converter 7 converts the received frequency
f1* into a phase amount Δθdq between the samplings.
The integrator 8 integrates the value Δθdq output
from the phase converter 7 to operate the magnetic
flux phase θdq. The voltage arithmetic unit 9
operates a primary voltage instruction V1* and a

voltage phase θ, by setting a q-axis voltage instruction Vq*' to zero or a value obtained by adding the received q-axis voltage instruction Vq* and the q-axis voltage correction value Vqc and by setting a d-axis voltage instruction Vd*' to the primary voltage correction value V1c or a value obtained by adding the d-axis voltage correction value Vdc and the d-axis voltage instruction Vd* given by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value Δθdq output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount Δθdq between the samplings. The

primary current controller 13 outputs a primary voltage correction value V1c so that the received primary current instruction i1* corresponds with the primary current detection value i1.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f1* corresponds with the DC braking initiation frequency, a process advances to a step 2b.

In a step 2a, the switches S1 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, a q-axis voltage instruction Vq*' obtained by adding the received q-axis voltage instruction Vq* and the q-axis voltage correction value Vqc, and a d-axis

voltage instruction Vd*' obtained by adding the received d-axis voltage instruction Vd* and the d-axis voltage correction value Vdc are input to the voltage arithmetic unit 9. The phase amount Δθdq between the samplings is operated by the phase converter 7 on the basis of the received frequency f1*, and the magnetic flux phase θdq is operated by the integrator 8. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq*' is set to zero (Vq*'=0), the d-axis voltage instruction Vd*' is output such that the primary current instruction i1* given for the DC braking corresponds with the primary current detection value i1, and the phase amount Δθdq between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a

process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and a value obtained by adding the voltage phase θv of the normal control state and the phase amount Δθdq operated in the step 2a is substituted for the magnetic flux phase θdq to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θdq.

In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase

prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 4

[0024]

Fig. 5 is a block diagram illustrating a control device of an induction motor for applying a method according to the fourth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a torque current controller 5, an excitation current controller 6, a phase converter 7, an integrator 8,

a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value iq and an excitation current detection value id. In addition, the primary current detection value i1 is output. The torque current controller 5 operates the q-axis voltage correction value Vqc so that a received torque current instruction value iq* corresponds with the torque current detection value iq. The excitation current controller 6 operates the d-axis voltage correction value Vdc so that the received excitation current instruction value id* corresponds with the excitation current detection value id. The phase converter 7 converts the received frequency f1* into a phase amount Δθdq between the samplings. The integrator 8 integrates the value Δθdq output

from the phase converter 7 to operate the magnetic flux phase θdq. The voltage arithmetic unit 9 operates a primary voltage instruction V1* and a voltage phase θ, by setting the q-axis voltage instruction Vq*' to the primary voltage correction value V1c or a value obtained by adding the q-axis voltage instruction Vq* given by the switch S1 and the q-axis voltage correction value Vqc and by setting a d-axis voltage instruction Vd*' to zero or a value obtained by adding the d-axis voltage instruction Vd* given by the switch S4 and the d-axis voltage correction value Vdc. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value $\Delta\theta$dq output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation

frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount Δθdq between the samplings. The primary current controller 13 outputs a primary voltage correction value V1c so that the received primary current instruction i1* corresponds with the primary current detection value i1.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f1* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, a q-axis voltage instruction Vq*'

obtained by adding the received q-axis voltage instruction Vq* and the q-axis voltage correction value Vqc, and a d-axis voltage instruction Vd*' obtained by adding the received d-axis voltage instruction Vd* and the d-axis voltage correction value Vdc are input to the voltage arithmetic unit 9. The phase amount Δθdq between the samplings is operated by the phase converter 7 on the basis of the received frequency f1*, and the magnetic flux phase θdq is operated by the integrator 8. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq*' is set to zero (Vq*'=0), the d-axis voltage instruction Vd*' is output such that the primary current instruction i1* given for the DC braking corresponds with the primary current detection value i1, and the phase amount Δθdq between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process

advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the voltage phase θv of the normal control state is rotated by 90°. However, its rotation direction is determined by the sign of the received frequency f1*. A value obtained by adding this phase angle and the phase amount Δθdq operated in the step 2a is substituted for the magnetic flux phase θdq so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θdq.

    In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction

Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 5

[0025]

Fig. 6 is a block diagram illustrating a control device of an induction motor for applying a method according to the fifth embodiment of the present invention. The control device of an

induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, an excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value iq and an excitation current detection value id. The excitation current controller 6 operates the d-axis voltage correction value Vdc so that the received excitation current instruction value id* corresponds with the excitation current detection value id. The phase converter 7 converts the received frequency f1* into a phase amount Δθdq between the samplings. The integrator 8 integrates the value Δθdq output from the phase converter 7 to operate the magnetic flux

phase θdq. The voltage arithmetic unit 9 operates a primary voltage instruction V1* and a voltage phase θ, by inputting zero or the q-axis voltage instruction Vq* given by the switch S1 as a q-axis voltage instruction Vq*' and by inputting zero or the d-axis voltage correction value Vdc as a d-axis voltage instruction Vd*' by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value Δθdq output from the phase predictor. The phase detector 12 predictably calculates the velocity of the AC motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount Δθdq between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be

described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f1* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S4 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction Vq*' is set to the received q-axis voltage instruction Vq*, and the d-axis voltage instruction Vd*' is set to zero (Vd*'=0), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount Δθdq between the samplings is operated by the phase converter 7 based on the received frequency f1*, and the integrator 8 operates the magnetic flux phase θdq. In the step 2b, as a process of switching over from the normal control state to the DC braking

state, the switches S1, S2, and S4 are switched over
from the side of "a" to the side of "b". Accordingly,
the q-axis voltage instruction Vq*' is set to zero
(Vq*'=0), the d-axis voltage instruction Vd*' is
output such that the excitation current instruction
id* given for the DC braking corresponds with the
excitation current detection value id, and the phase
amount Δθdq between the samplings is predictably
calculated by the phase detector 12 on the basis of
the DC braking initiation frequency or a
relationship between the DC braking initiation
frequency and the decelerating rate to obtain the
velocity of the induction motor 2. Then, a process
advances to a step 3, in which it is determined
whether the FLG is "0" or "1". If the FLG is "0", a
process advances to a step 4a. If the FLG is "1", a
process advances to a step 4b. In the step 4a, the
switch S3 is switched over from the side of "a" to
the side of "b" in only one time at the instant that
the switch-over to the DC braking state is performed,
and a value obtained by the voltage phase θv of the
normal control state and the phase amount Δθdq
obtained in the step 2a is substituted for the
magnetic flux phase θdq, so as to match the phases
between the normal control state and the DC braking

initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θdq.

In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the AC motor 2 by predicting the velocity of the AC motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through

this method, since the current phase is not abruptly
changed regardless of an electromotive load or a
restoration load, the torque shock can be reduced to
a predetermined value or less.

Embodiment 6

[0026]

Fig. 7 is a block diagram illustrating a
control device of an induction motor for applying a
method according to the sixth embodiment of the
present invention. The control device of an
induction motor according to the present embodiment
includes a power converter 1, an AC motor 2, a
current detector 3, a d-q converter 4, a phase
converter 7, an integrator 8, a voltage arithmetic
unit 9, a PWM arithmetic unit 10, a voltage phase
prediction arithmetic unit 11, a phase predictor 12,
a primary current controller 13, and switches S1, S2,
S3, and S4. The power converter 1 converts a three
phase AC current into a DC voltage having a
predetermined frequency and voltage using a power
element through a PWM control method and supplies it
to the AC motor 2. The current detector 3 detects
the current supplied to the AC motor 2. The d-q
converter 4 separates the current detected by the
current detector 3 into a torque current detection

value iq and an excitation current detection value
id. In addition, a primary current detection value
i1 is output. The phase converter 7 converts the
received frequency f1* into a phase amount Δθdq
between the samplings. The integrator 8 integrates
the value Δθdq output from the phase converter 7 to
operate the magnetic flux phase θdq. The voltage
arithmetic unit 9 operates a primary voltage
instruction V1* and a voltage phase θ, by inputting
zero or the q-axis voltage instruction Vq* given by
the switch S1 as a q-axis voltage instruction Vq*'
and by inputting zero or the primary voltage
correction value V1c as the d-axis voltage
instruction Vd*' by the switch S4. The PWM
arithmetic unit 10 determines a switching pattern of
the power converter 1 based on the primary voltage
instruction V1* and the output phase θv obtained by
adding the voltage phase θ and the magnetic flux
phase θdq.

The voltage phase prediction arithmetic unit 11
predictably operates the voltage phase based on the
output phase during a switch-over from the normal
control state to the DC braking state and the value
Δθdq output from the phase predictor. The phase
detector 12 predictably calculates the velocity of

the AC motor 2 for a switch-over from the normal
control state to the DC braking state on the basis
of a DC braking initiation frequency or a
relationship between the DC braking initiation
frequency and a deceleration rate, and converts it
to a phase amount Δθdq between the samplings. The
primary current controller 13 outputs the primary
voltage correction value V1c such that the received
primary current instruction i1* corresponds with the
primary current detection value i1.

Specifically, a step of switching over from the
normal control state to the DC braking state will be
described with reference to Fig. 2. A step 1 is a
step of determining a DC braking state and a normal
control state. In this step, it is determined
whether or not the received frequency f1*
corresponds with the DC braking initiation frequency
fdb during a deceleration. If the received frequency
f1* is higher than the DC braking initiation
frequency, a process advances to a step 2a as the
normal control state. If the received frequency f1*
corresponds with the DC braking initiation frequency,
a process advances to a step 2b. In a step 2a, the
switches S1 to S4 are operated in the side of "a" as
the normal control state, and the FLG is set to zero

(FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction Vq*' is set to the received q-axis voltage instruction Vq*, and the d-axis voltage instruction Vd*' is set to zero (Vd*'=0), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount Δθdq between the samplings is operated by the phase converter 7 based on the received frequency f1*, and the integrator 8 operates the magnetic flux phase θdq. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq*' is set to zero (Vq*'=0), the d-axis voltage instruction Vd*' is set to the primary voltage correction value V1c operated such that the primary current instruction i1* given for a DC braking corresponds with the primary current detection value i1, and the phase amount Δθdq between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the AC

motor 2. Then, a process advances to a step 3, in
which it is determined whether the FLG is "0" or "1".
If the FLG is "0", a process advances to a step 4a.
If the FLG is "1", a process advances to a step 4b.
In the step 4a, the switch S3 is switched over from
the side of "a" to the side of "b" in only one time
at the instant that the switch-over to the DC
braking state is performed, and a value obtained by
the voltage phase θv of the normal control state and
the phase amount Δθdq obtained in the step 2a is
substituted for the magnetic flux phase θdq, so as
to match the phases between the normal control state
and the DC braking initiation.

In addition, the FLG is set to one (FLG=1) in
order to perform this operation in only one time,
and a process advances to a step of the PWM
arithmetic unit. In the step 4b, since the switch S3
is maintained in the side of "a", any particular
processing is not performed for the phase θdq.

In the step of the PWM arithmetic unit, the
primary voltage instruction V1* and the voltage
phase θ are operated from the d-axis voltage
instruction Vd*' and the q-axis voltage instruction
Vq*', and the output phase θv is operated from the
voltage phase θ and the magnetic flux phase θdq, so

that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the AC motor 2 by predicting the velocity of the AC motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 7

[0027]

Fig. 8 is a block diagram illustrating a control device of an induction motor for applying a method according to the seventh embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, an

excitation current controller 6, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value iq and an excitation current detection value id. The excitation current controller 6 operates the d-axis voltage correction value Vdc so that the received excitation current instruction value id* corresponds with the excitation current detection value id. The phase converter 7 converts the received frequency f1* into a phase amount Δθdq between the samplings. The integrator 8 integrates the value Δθdq output from the phase converter 7 to operate the magnetic flux phase θdq. The voltage arithmetic unit 9 operates a primary voltage instruction V1* and a voltage phase θ, by setting a q-axis voltage instruction Vq*' to

zero or the q-axis voltage instruction Vq* given by the switch S1 and by setting a d-axis voltage instruction Vd*' to zero or the d-axis voltage correction value Vdc by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value Δθdq output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount Δθdq between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal

control state. In this step, it is determined
whether or not the received frequency f1*
corresponds with the DC braking initiation frequency
fdb during a deceleration. If the received frequency
f1* is higher than the DC braking initiation
frequency, a process advances to a step 2a as the
normal control state. If the received frequency f1*
corresponds with the DC braking initiation frequency,
a process advances to a step 2b. In a step 2a, the
switches S1 to S4 are operated in the side of "a" as
the normal control state, and the FLG is set to zero
(FLG=0), so that a process advances to a step of the
PWM arithmetic unit which will be described below.
In this case, a q-axis voltage instruction Vq* is
set to the received q-axis voltage instruction Vq*,
and the d-axis voltage instruction Vd* is set to
zero (Vd*'=0), so that they are input to the voltage
arithmetic unit 9. Accordingly, the phase amount
Δθdq between the samplings is operated by the phase
converter 7 based on the received frequency f1*, and
the integrator 8 operates the magnetic flux phase
θdq. In the step 2b, as a process of switching over
from the normal control state to the DC braking
state, the switches S1, S2, and S4 are switched over
from the side of "a" to the side of "b". Accordingly,

the q-axis voltage instruction Vq* is set to zero (Vq*'=0), the d-axis voltage instruction Vd* is output such that the received current instruction id* given for the DC control corresponds with the d-axis current detection value id, and the phase amount Δθdq between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the phase θdq of the magnetic flux of the normal control state is rotated by 90˚. However, its rotation direction is determined by the sign of the received frequency f1*. A value obtained by adding this phase angle and the phase amount Δθdq operated in the step 2a is substituted for the magnetic flux phase θdq, so as to match the phases between the

normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θdq.

In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In

addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 8

[0028]

Fig. 9 is a block diagram illustrating a control device of an induction motor for applying a method according to the eighth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, S3, and S4. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the AC motor 2. The d-q converter 4 separates the current detected by

the current detector 3 into a torque current detection value iq and an excitation current detection value id. In addition, a primary current detection value i1 is output. The phase converter 7 converts the received frequency f1* into a phase amount Δθdq between the samplings. The integrator 8 integrates the value Δθdq output from the phase converter 7 to operate the magnetic flux phase θdq. The voltage arithmetic unit 9 operates a primary voltage instruction V1* and a voltage phase θ, by setting a q-axis voltage instruction Vq*' to zero or the q-axis voltage instruction Vq* given by the switch S1 and by setting a d-axis voltage instruction Vd*' to zero or the primary voltage correction value V1c by the switch S4. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value Δθdq output from the phase predictor. The phase detector 12 predictably calculates the

velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta dq$ between the samplings. The primary current controller 13 outputs the primary voltage correction value V1c such that the received primary current instruction i1* corresponds with the primary current detection value i1.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f1* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S4 are operated in the side of "a" as

the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction Vq*' is set to the received q-axis voltage instruction Vq*, and the d-axis voltage instruction Vd*' is set to zero (Vd*'=0), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount Δθdq between the samplings is operated by the phase converter 7 based on the received frequency f1*, and the integrator 8 operates the magnetic flux phase θdq. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1, S2, and S4 are switched over from the side of "a" to the side of "b". Accordingly, the q-axis voltage instruction Vq*' is set to zero (Vq*'=0), the primary voltage correction value V1c operated such that the primary current instruction i1* given for a DC control corresponds with the primary current detection value i1 is output as the d-axis voltage instruction Vd*', and the phase amount Δθdq between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation

frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the magnetic flux phase θdq of the normal control state is rotated by 90˚. However, its rotation direction is determined by the sign of the received frequency f1*. A value obtained by adding this phase angle and the phase amount Δθdq operated in the step 2a is substituted for the magnetic flux phase θdq, so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θdq.

In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage

phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 9

    [0029]

    Fig. 10 is a block diagram illustrating a control device of an induction motor for applying a

method according to the ninth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a torque current controller 5, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S1, S2, and S3. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value iq and an excitation current detection value id. In addition, a primary current detection value i1 is output. The torque current controller 5 operates the q-axis voltage correction value Vqc such that the received excitation current instruction value id* corresponds with the torque current detection value iq. The phase converter 7 converts the received frequency

f1* into a phase amount Δθdq between the samplings. The integrator 8 integrates the value Δθdq output from the phase converter 7 to operate the magnetic flux phase θdq. The voltage arithmetic unit 9 operates a primary voltage instruction V1* and a voltage phase θ, by setting a q-axis voltage instruction Vq*' to a q-axis voltage correction value Vqc or the q-axis voltage instruction Vq* given by the switch S1 and by setting a d-axis voltage instruction Vd*' to zero. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value Δθdq output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it

to a phase amount Δθdq between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f1* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S3 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, a q-axis voltage instruction Vq* is set to the received q-axis voltage instruction Vq*, and the d-axis voltage instruction Vd* is set to zero (Vd*'=0), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount Δθdq between the samplings is operated by the phase converter 7 based on the received frequency f1*, and

the integrator 8 operates the magnetic flux phase θdq. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1 and S2 are switched over from the side of "a" to the side of "b". Accordingly, the d-axis voltage instruction Vd*' is set to zero (Vd*'=0), the q-axis voltage correction value Vqc operated such that the received current instruction iq* given for the DC control corresponds with the q-axis current detection value iq is output as the q-axis voltage instruction Vq*', and the phase amount Δθdq between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only one time at the instant that the switch-over to the DC braking state is performed, and the voltage phase θv of the normal control state is rotated by 90°.

However, its rotation direction is determined by the sign of the received frequency f1*. A value obtained by adding this phase angle and the phase amount Δθdq operated in the step 2a is substituted for the magnetic flux phase θdq, so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θdq. In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when

a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 10

[0030]

Fig. 11 is a block diagram illustrating a control device of an induction motor for applying a method according to the tenth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, and S3. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined

frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the AC motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value iq and an excitation current detection value id. In addition, a primary current detection value i1 is output. The phase converter 7 converts the received frequency f1* into a phase amount Δθdq between the samplings. The integrator 8 integrates the value Δθdq output from the phase converter 7 to operate the magnetic flux phase θdq. The voltage arithmetic unit 9 operates a primary voltage instruction V1* and a voltage phase θ, by setting a q-axis voltage instruction Vq*' to the q-axis voltage instruction Vq* given by the switch S1 or the primary voltage correction value V1c and by setting a d-axis voltage instruction Vd*' to zero. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase prediction arithmetic unit 11 predictably operates

the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value Δθdq output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount Δθdq between the samplings. The primary current controller 13 outputs the primary voltage correction value V1c such that the received primary current instruction i1* corresponds with the primary current detection value i1.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation frequency, a process advances to a step 2a as the

normal control state. If the received frequency f1*
corresponds with the DC braking initiation frequency,
a process advances to a step 2b. In a step 2a, the
switches S1 to S3 are operated in the side of "a" as
the normal control state, and the FLG is set to zero
(FLG=0), so that a process advances to a step of the
PWM arithmetic unit which will be described below.
In this case, the q-axis voltage instruction Vq*' is
set to the received q-axis voltage instruction Vq*,
and the d-axis voltage instruction Vd*' is set to
zero (Vd*'=0), so that they are input to the voltage
arithmetic unit 9. Accordingly, the phase amount
Δθdq between the samplings is operated by the phase
converter 7 based on the received frequency f1*, and
the integrator 8 operates the magnetic flux phase
θdq. In the step 2b, as a process of switching over
from the normal control state to the DC braking
state, the switches S1 and S2, are switched over
from the side of "a" to the side of "b". Accordingly,
the d-axis voltage instruction Vd*' is set to zero
(Vd*'=0), the primary voltage correction value V1c
operated such that the primary current instruction
i1* given for a DC control corresponds with the
primary current detection value i1 is output as the
q-axis voltage instruction Vq*', and the phase

amount $\Delta\theta dq$ between the samplings is predictably
calculated by the phase detector 12 on the basis of
the DC braking initiation frequency or a
relationship between the DC braking initiation
frequency and the decelerating rate to obtain the
velocity of the induction motor 2. Then, a process
advances to a step 3, in which it is determined
whether the FLG is "0" or "1". If the FLG is "0", a
process advances to a step 4a. If the FLG is "1", a
process advances to a step 4b. In the step 4a, the
switch S3 is switched over from the side of "a" to
the side of "b" in only one time at the instant that
the switch-over to the DC braking state is performed,
and the voltage phase θv of the normal control state
is rotated by 90°. However, its rotation direction
is determined by the sign of the received frequency
f1*. A value obtained by adding this phase angle and
the phase amount $\Delta\theta dq$ operated in the step 2a is
substituted for the magnetic flux phase θdq, so as
to match the phases between the normal control state
and the DC braking initiation. In addition, the FLG
is set to one (FLG=1) in order to perform this
operation in only one time, and a process advances
to a step of the PWM arithmetic unit. In the step 4b,
since the switch S3 is maintained in the side of "a",

any particular processing is not performed for the phase θdq. In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 11

[0031]

Fig. 12 is a block diagram illustrating a control device of an induction motor for applying a method according to the eleventh embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a torque current controller 5, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, and switches S1, S2, and S3. The power converter 1 converts a three phase AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the induction motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value iq and an excitation current detection value id. In addition, a primary current detection value i1 is output. The torque current controller 5 operates the q-axis voltage correction value Vqc such that the received

excitation current instruction value id* corresponds
with the torque current detection value iq.   The
phase converter 7 converts the received frequency
f1* into a phase amount Δθdq between the samplings.
The integrator 8 integrates the value Δθdq output
from the phase converter 7 to operate the magnetic
flux phase θdq.   The voltage arithmetic unit 9
operates a primary voltage instruction V1* and a
voltage phase θ, by setting a q-axis voltage
instruction Vq*' to a q-axis voltage correction
value Vqc or the q-axis voltage instruction Vq*
given by the switch S1 and by setting a d-axis
voltage instruction Vd*' to zero.   The PWM arithmetic
unit 10 determines a switching pattern of the power
converter 1 based on the primary voltage instruction
V1* and the output phase θv obtained by adding the
voltage phase θ and the magnetic flux phase θdq.   The
voltage phase prediction arithmetic unit 11
predictably operates the voltage phase based on the
output phase during a switch-over from the normal
control state to the DC braking state and the value
Δθdq output from the phase predictor.   The phase
detector 12 predictably calculates the velocity of
the induction motor 2 for a switch-over from the
normal control state to the DC braking state on the

basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount $\Delta\theta dq$ between the samplings.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation frequency, a process advances to a step 2a as the normal control state. If the received frequency f1* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S3 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, a q-axis voltage instruction Vq* is set to the received q-axis voltage instruction Vq*, and the d-axis voltage instruction Vd* is set to zero (Vd*'=0), so that they are input to the voltage

arithmetic unit 9. Accordingly, the phase amount Δθdq between the samplings is operated by the phase converter 7 based on the received frequency f1*, and the integrator 8 operates the magnetic flux phase θdq. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1 and S2 are switched over from the side of "a" to the side of "b". Accordingly, the d-axis voltage instruction Vd*' is set to zero (Vd*'=0), the q-axis voltage correction value Vqc operated such that the received current instruction iq* given for the DC control corresponds with the q-axis current detection value iq is output as the q-axis voltage instruction Vq*', and the phase amount Δθdq between the samplings is predictably calculated by the phase detector 12 on the basis of the DC braking initiation frequency or a relationship between the DC braking initiation frequency and the decelerating rate to obtain the velocity of the induction motor 2. Then, a process advances to a step 3, in which it is determined whether the FLG is "0" or "1". If the FLG is "0", a process advances to a step 4a. If the FLG is "1", a process advances to a step 4b. In the step 4a, the switch S3 is switched over from the side of "a" to the side of "b" in only

one time at the instant that the switch-over to the DC braking state is performed, and a value obtained by adding the magnetic flux phase θdq of the normal control state and the phase amount Δθdq operated in the step 2a is substituted for the magnetic flux phase θdq, so as to match the phases between the normal control state and the DC braking initiation. In addition, the FLG is set to one (FLG=1) in order to perform this operation in only one time, and a process advances to a step of the PWM arithmetic unit. In the step 4b, since the switch S3 is maintained in the side of "a", any particular processing is not performed for the phase θdq.

In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the

induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

Embodiment 12

[0032]

Fig. 13 is a block diagram illustrating a control device of an induction motor for applying a method according to the twelfth embodiment of the present invention. The control device of an induction motor according to the present embodiment includes a power converter 1, an induction motor 2, a current detector 3, a d-q converter 4, a phase converter 7, an integrator 8, a voltage arithmetic unit 9, a PWM arithmetic unit 10, a voltage phase prediction arithmetic unit 11, a phase predictor 12, a primary current controller 13, and switches S1, S2, and S3. The power converter 1 converts a three phase

AC current into a DC voltage having a predetermined frequency and voltage using a power element through a PWM control method and supplies it to the induction motor 2. The current detector 3 detects the current supplied to the AC motor 2. The d-q converter 4 separates the current detected by the current detector 3 into a torque current detection value iq and an excitation current detection value id. In addition, a primary current detection value i1 is output. The phase converter 7 converts the received frequency f1* into a phase amount Δθdq between the samplings. The integrator 8 integrates the value Δθdq output from the phase converter 7 to operate the magnetic flux phase θdq. The voltage arithmetic unit 9 operates a primary voltage instruction V1* and a voltage phase θ, by setting a q-axis voltage instruction Vq*' to the q-axis voltage instruction Vq* given by the switch S1 or the primary voltage correction value V1c and by setting a d-axis voltage instruction Vd*' to zero. The PWM arithmetic unit 10 determines a switching pattern of the power converter 1 based on the primary voltage instruction V1* and the output phase θv obtained by adding the voltage phase θ and the magnetic flux phase θdq. The voltage phase

prediction arithmetic unit 11 predictably operates the voltage phase based on the output phase during a switch-over from the normal control state to the DC braking state and the value Δθdq output from the phase predictor. The phase detector 12 predictably calculates the velocity of the induction motor 2 for a switch-over from the normal control state to the DC braking state on the basis of a DC braking initiation frequency or a relationship between the DC braking initiation frequency and a deceleration rate, and converts it to a phase amount Δθdq between the samplings. The primary current controller 13 outputs the primary voltage correction value V1c such that the received primary current instruction i1* corresponds with the primary current detection value i1.

Specifically, a step of switching over from the normal control state to the DC braking state will be described with reference to Fig. 2. A step 1 is a step of determining a DC braking state and a normal control state. In this step, it is determined whether or not the received frequency f1* corresponds with the DC braking initiation frequency fdb during a deceleration. If the received frequency f1* is higher than the DC braking initiation

frequency, a process advances to a step 2a as the normal control state. If the received frequency f1* corresponds with the DC braking initiation frequency, a process advances to a step 2b. In a step 2a, the switches S1 to S3 are operated in the side of "a" as the normal control state, and the FLG is set to zero (FLG=0), so that a process advances to a step of the PWM arithmetic unit which will be described below. In this case, the q-axis voltage instruction Vq*' is set to the received q-axis voltage instruction Vq*, and the d-axis voltage instruction Vd*' is set to zero (Vd*'=0), so that they are input to the voltage arithmetic unit 9. Accordingly, the phase amount Δθdq between the samplings is operated by the phase converter 7 based on the received frequency f1*, and the integrator 8 operates the magnetic flux phase θdq. In the step 2b, as a process of switching over from the normal control state to the DC braking state, the switches S1 and S2 are switched over from the side of "a" to the side of "b". Accordingly, the d-axis voltage instruction Vd*' is set to zero (Vd*'=0), the primary voltage correction value V1c operated such that the primary current instruction i1* given for a DC control corresponds with the primary current detection value i1 is output as the

q-axis voltage instruction Vq*', and the phase
amount Δθdq between the samplings is predictably
calculated by the phase detector 12 on the basis of
the DC braking initiation frequency or a
relationship between the DC braking initiation
frequency and the decelerating rate to obtain the
velocity of the induction motor 2. Then, a process
advances to a step 3, in which it is determined
whether the FLG is "0" or "1". If the FLG is "0", a
process advances to a step 4a. If the FLG is "1", a
process advances to a step 4b. In the step 4a, the
switch S3 is switched over from the side of "a" to
the side of "b" in only one time at the instant that
the switch-over to the DC braking state is performed,
and a value obtained by adding the voltage phase θv
of the normal control state and the phase amount
Δθdq operated in the step 2a is substituted for the
magnetic flux phase θdq, so as to match the phases
between the normal control state and the DC braking
initiation. In addition, the FLG is set to one
(FLG=1) in order to perform this operation in only
one time, and a process advances to a step of the
PWM arithmetic unit. In the step 4b, since the
switch S3 is maintained in the side of "a", any
particular processing is not performed for the phase

θdq.

In the step of the PWM arithmetic unit, the primary voltage instruction V1* and the voltage phase θ are operated from the d-axis voltage instruction Vd*' and the q-axis voltage instruction Vq*', and the output phase θv is operated from the voltage phase θ and the magnetic flux phase θdq, so that they are set in the PWM arithmetic unit 10 to drive the power converter 1.

Through the steps in the voltage phase prediction arithmetic unit 11, it is possible to accurately predict the magnetic flux phase of the induction motor 2 by predicting the velocity of the induction motor 2 using the phase predictor 12 when a switch-over from the normal control state to the DC braking state is performed. Therefore, the current phase is not abruptly changed when the DC braking is initiated, so that the torque shock can be reduced to a predetermined value or less. In addition, through this method, since the current phase is not abruptly changed regardless of an electromotive load or a restoration load, the torque shock can be reduced to a predetermined value or less.

The present invention may be employed not only

in an induction motor control device that uses, so called, a sensor less vector control method but also in a vector control device having a sensor or a control device that uses a V/f control method.

Industrial Applicability

[0033]

According to the present invention, it is possible to reduce the torque shock generated by an abrupt change of the output current phase to a predetermined value or less by predictably operating an output voltage phase during a DC braking on the basis of an output voltage phase of a normal control state when a switch-over from the normal control state to the DC braking state is performed. Therefore, the present invention may be employed in a usage for preventing an induction motor from being not rotated until the brake is closed, such as an application for determining a position or an elevating machinery(for example, an elevator, a crane, and a hoist).